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Cosmetic obsolescence? User perceptions of new and artificially aged materials



D. Lilley^a, G. Smalley^a, B. Bridgens^{b,*}, G.T. Wilson^a, K. Balasundaram^b

^a Loughborough University, Loughborough Design School, Leicestershire LE11 3TU, UK

^b Newcastle University, School of Civil Engineering and Geosciences, Newcastle-upon-Tyne, NE1 7RU, UK

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ABSTRACT

This paper presents the findings of a user study which explored tactile and aesthetic responses to new and artificially aged mobile phone cases made from bamboo, walnut, cork, leather, brushed titanium, plastic and rubber. The paper outlines test methods for accelerated ageing of the external enclosures of consumer electronics based on the types of wear experienced in use, and the use of semantic differential scales (SDS) to probe user attitudes to these materials. The results indicate that preferences for the materials tested were extremely subjective, and even a single participant can have conflicting requirements for the characteristics of the materials (for example, sleek and shiny yet easy to grip). Whilst in general participants preferred the new materials and saw the ageing process as negative, there were examples where the aged samples either scored more highly due to durability (titanium) or received positive comments about the aesthetic changes caused by severe ageing (bamboo and leather). This study captured the participants' immediate, visceral response to the materials, which may be very different to their feelings towards materials and objects that they have owned and interacted with for a period of time.

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1. Introduction

The rapid turnover of consumer electronics, fuelled by increased consumption, has resulted in negative global environmental, social, and economic consequences [57]. Electronic waste (e-waste) is typically disposed of into UK landfills or to developing countries, incinerated, stored in a redundant state (also known as 'hibernating') or otherwise 'lost' – very few are effectively recycled. Materials scarcity of non-renewable, finite resources is a global concern and one that UK consumers and manufacturers cannot ignore. To use these resources more efficiently and reduce e-waste, consumers must be encouraged to retain their devices for longer and return them at the end of their life (or before). To assist in a transition from the current throw-away society towards a circular economy, the UK Engineering and Physical Sciences Research Council funded the CLEVER project (2013–2016) which is developing materials which aim to engender emotional attachment to the external enclosure of fast moving consumer electronic devices, to motivate continued usage and facilitate the return of the internal electronics for upgrade rather than disposal. The aim is to enable the efficient recovery of the valuable, high impact metals in the internal electronics and allow them to be re-used in a closed loop.

2. Literature review

Although it is hard to quantify with any precision, it is widely considered that the 20th century saw a downward trend in the lifetime of products [16,43,48]. This trend has continued since 2001 with a 10 to 20% reduction in the time that EU consumers keep household appliances before disposal [22,31]. The Organisation for Economic Co-operation and Development (OECD) identified that the long-term increase in income and access to credit has also seen a rise in the total number of objects that households own [39]. According to the Office for National Statistics (ONS), only with the financial crisis of 2008 has household consumption reduced, but even this period of slowing returned to growth at the end of 2011 [37]. This level of consumption has led to an associated rise in household waste, which currently stands at over 22 million tonnes a year [38] in England alone, with almost one million tonnes of this coming from electrical and electronic equipment [23]. The impact of increasing household waste has been partially mitigated by improved recycling rates, which have climbed from 10% to 40% in the last decade [17], but recycling (or often 'downcycling') only offers a 'least bad' solution to waste [6,16]. Recycling infrastructure including transportation and processing consumes significant amounts of energy, as does reusing the recovered materials [15], so it cannot effectively close the consumption loop. Furthermore, recycling rates are levelling off [17] so as consumption continues to climb, the levels of waste will increase. Recycling cannot mitigate the impacts of the consumer society by itself, and five times as much waste is created during

* Corresponding author.

E-mail addresses: d.lilley@lboro.ac.uk (D. Lilley), g.smalley@lboro.ac.uk (G. Smalley), ben.bridgens@newcastle.ac.uk (B. Bridgens), g.t.wilson@lboro.ac.uk (G.T. Wilson), keerthika.balasundaram@newcastle.ac.uk (K. Balasundaram).

the manufacturing process than remains when a product is disposed of at the end of its life [32].

“The circular economy represents a development strategy that maximises resource efficiency and minimises waste production, within the context of sustainable economic and social development” ([60], p. 2). Greater circularity could mitigate lifecycle impacts (Hislop & Hill, 2011), but circular economy may not be enough on its own to realise a sustainable system if the consumption of resources continues to increase as this would offset any improvements in efficiency [16]. So, it is also necessary to reduce the rate at which resources are consumed by slowing replacement cycles [16,61]. Lifetime optimization is recognized as a key resource efficiency strategy [10,62]. Designers are well-versed in designing for longer-life through increased material robustness, physical durability and design for repair and maintenance. Achieving a long-lasting emotional connection, however, is far more challenging particularly in today's consumerist society in which credit is plentiful and a culture of instant gratification prevails.

The reasons for obsolescence can be broadly grouped as technical (new products incorporate technological advances), functional (the product no longer works) and aesthetic (the new product looks more desirable) [16,43]. Consumer electronics *“tend to occupy a synthetic and scratch-free world of slick polymers...”* ([11], p. 141) with wear and damage to the pristine external enclosure widely considered to contribute to premature replacement of ‘tired’, ‘worn’ or ‘damaged’ devices [20, 35,36]. The prominent aesthetic change caused by minor wear and damage to pristine enclosures, combined with incremental upgrades in hardware and regular tweaks to styling all contribute to the rapid turnover of these devices. This research focuses on addressing *“cosmetic obsolescence”*, the physical changes that occur on a product or material over the use period that alters the perceived look and feel of a product or material resulting in a shortened product lifespan [29].

Natural materials including wood, leather, stone and some metals are commonly described as ‘ageing gracefully’ and develop a ‘patina’ which is valued more highly than the new material [9,36,45,49]. Depending on the material, this ‘patina’ is caused by gentle wear and polishing, and reaction to ultraviolet light and/or chemicals (typically water and oxygen). Examples include ‘verdigris’ – the durable, green surface finish of weathered copper which is highly valued as a building cladding material, and complex changes in wood due to weathering which tend to emphasise both the visual appearance and texture of the grain [19]. The manufacturing process and surface finish are also crucial in determining the final appearance and ageing behaviour of the material [45]. In stark contrast, man-made materials such as plastic, glass and stainless steel are manufactured in a pristine, shiny, uniform state and as such do not provide the potential for timeless beauty [54]. It has been suggested that the ‘temporary shininess’ of consumer goods as a material quality reflects the transient and superficial nature of postmodern culture [28]. In contrast to the formation of ‘patina’ described above, the effects of wear, ultraviolet light and chemicals have deleterious effects on these materials. Plastic objects can start life delighting us with their pleasurable sensorial properties (smoothness and glossiness), however, after a short time our pleasure turns to disgust due to the deterioration of these properties [20]. The discolouration of plastics due to UV exposure is particularly unappealing, both aesthetically and functionally as the material may become brittle. The associated loss in perceived value can lead to dissatisfaction [8,50] reducing the lifespan of certain products through premature disposal in favour of a ‘shiny new one’.

Previous studies have revealed meanings embedded within specific materials, such as metal implying precision and technological superiority [25]; metallic materials with smooth surfaces eliciting positive emotional responses and rough metallic surfaces eliciting negative emotional responses [58]; as well as plastic being considered the most displeasurable and least pleasurable family of materials [4]. However, most studies utilize new rather than aged materials and as such fail to account for material changes attributable to wear and the resulting

effect on user perceptions. Yet, as discussed previously, ‘newness’ or ‘shininess’ within consumer electronics is a fleeting material quality and dissatisfaction can ensue as a result of temporal material changes. Chapman [11] proposes that materials which physically age well and develop a tangible character through time and use may potentially engender greater emotional value, offering a viable pathway to longevity. The creation of a patina writes a narrative into the materials of the product, and through this a shared history is expressed; *“whether deliberate or unintentional, every crack and scratch that materials manifest as we interact with objects inscribes a story”* ([21], p. 473; [46]). Patina is not *“to do with material resilience or durability, but rather, a societal preoccupation with what an appropriate condition is for certain typologies of materials and objects to be in”* ([11], p. 141). Unfortunately the distinction between ‘patina’ and ‘degradation’ is not well defined, and is highly subjective. In addition, little is known about attitudinal responses to ‘aged materials’ nor the potential for value to be ascribed to incidents of material change. Given the resurgence of interest in the ‘materiality of interaction’ with digital devices [53] this paper makes a timely contribution to address these questions.

3. Methods

The following section reflects on the methods employed for material preparation, data collection and analysis of the user study, aiming to uncover and explore users' tactile and aesthetic responses to new and aged portable consumer electronics.

Consumers interact with materials through products [2]. The function of an object directly affects the way we perceive the materials from which it is made and what these materials express [24,25]. Yet few material studies exploring tactile and aesthetic preferences focus on individual products – most utilize small swatches of material devoid of context (e.g. [42,58]). To counter this limitation of previous studies, and to link perceptions to a relevant product, mobile phone cases made from a range of materials have been used as a rapid, cost effective method of allowing people to interact with the same object enclosed in different materials.

3.1. Preparation of artificially aged mobile phones

Mobile phone cases made from lacquered bamboo, walnut, cork, leather, brushed titanium, plastic and rubber were used (Fig. 1). The materials were chosen to include typical man-made materials currently used for mobile phone exteriors (titanium, plastic and rubber), and a range of different natural materials (bamboo, walnut, cork and leather) to explore the different response to wear and ageing of ‘shiny’ man-made materials and textured, variable natural materials. One set remained in pristine, new condition, and the other was artificially aged.

Product testing of electronic devices by manufacturers typically focuses on avoidance of functional failure, not gradual wear and longevity, and there were no published methods or standards for accelerated wear testing for this type of product. Therefore, we developed test methods for accelerated ageing of consumer electronics based on the types of wear experienced in use and manufacturers' videos of their durability testing (link to video: https://www.youtube.com/watch?v=HicdXV_47V8). We divided the wide spectrum of possible degradation mechanisms into two processes:

1. Wear – analogous to careful use and handling, and carrying in a pocket or case, which will gradually polish the material over time. To accelerate this form of wear a handheld polisher was used with different grades of polishing disc for different materials. Whilst it would be desirable to standardise the test method for all materials, the effect of different grades and durations of polishing on different materials varies too widely, such that the test method must be tailored to each sample and a degree of ‘craftsmanship’ employed in applying a suitable amount of polishing to each sample.



Fig. 1. Mobile phone cases used in the study. New (top) and after severe ageing (bottom).

2. Damage - to simulate less careful use and storage, such as carrying the phone in a pocket with keys or dropping on a rough surface. For this test a standard method was used for all materials. Mobile phone cases were mounted on dummy phones within an acrylic cylinder with a selection of keys and coins which are free to move. Rotation of the cylinder results in impact between the keys and coins and phone case causing a gradual build-up of damage to the material surface (Fig. 2). The number of revolutions of the cylinder is used to control the severity of the damage.

In terms of Manley et al.'s [29] 'taxonomy of damage', polishing will cause minor, uniform abrasion, whilst tumbling with keys and coins will result in ablation, minor impact, and accumulated dirt. Two studies were carried out to simulate 'gentle wear' [7] and 'severe wear', with the findings of the 'severe wear' study being considered in this paper. To simulate severe wear the mobile phone cases were subjected to

61,440 cycles with keys and coins interspersed with two cycles of polishing.

Manley et al. [29] studied the condition of 50 mobile devices at different stages of ownership and reported that "The spread of the types of MC [material change] over self-reported periods of ownership indicated a correlation between the gradual increase of MC and length of ownership" - for devices to exhibit abrasion, ablation and accumulated dirt they are typically over 12 months old. Whilst device ageing is highly variable depending on the behaviour of the individual user, comparison with Manley et al. [29] shows that the 'severe wear' applied in this study is broadly representative of 12 to 24 months use.

3.2. Evaluation of user response

Participants aged 18–25 were recruited from the Loughborough University populace, avoiding programmes that may foster a greater

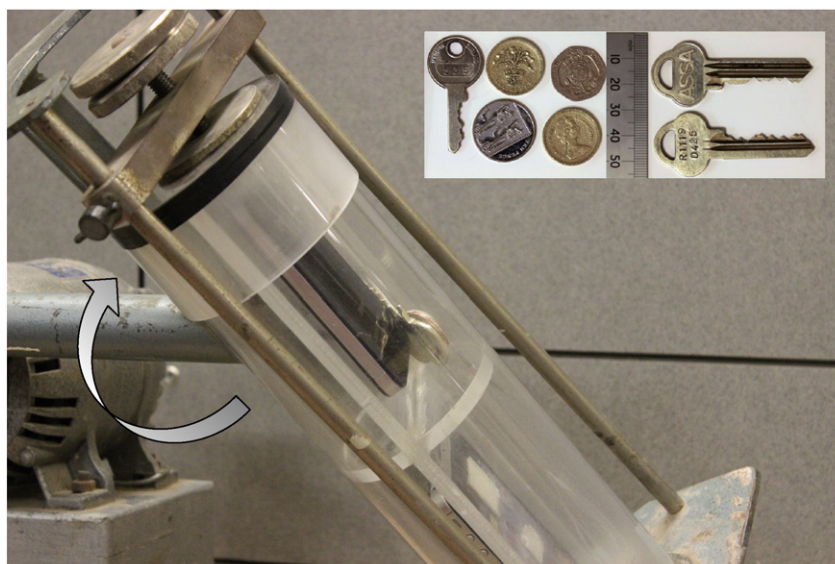


Fig. 2. Test set-up for accelerated ageing.



Fig. 3. Example of the test materials being placed on a semantic differential scale.

understanding of materials or design. British nationals were recruited to keep cultural influences to a minimum. 15 participants comprising 13 females and 2 males took part in the study. They were aged 19–23 with a mean age of 20. A range of semantic differential scales were employed alongside open-ended, discursive questions in a semi-structured interview format. The semantic differential scale (SDS), pioneered by Osgood et al. [41], is a linguistic tool which can be used to measure people's attitudes towards an event, object, topic or activity and provide insights into meanings behind such attitudes. The format used is a scale with bipolar word pairs at each end. A participant is provided with a concept or object and asked to place a mark on the scale which best describes their feelings towards the stimulus [30]. This method has been used extensively within materials studies (e.g., [13, 26, 33, 42]) and as such was considered an appropriate method to adopt due to its proven rigour and efficacy.

The study was conducted in two parts, in the first part the new sample materials were presented to the participants; the aged samples were then presented in part two. Each part comprised of two stages:

In Stage 1 the participants were blindfolded and each of the seven sample materials was placed in front of them. Restricting their sight forced participants to evaluate the samples purely on a tactile basis. This is common practice in other comparable studies (e.g. [13, 56]) as it pulls focus towards touch rather than sight as the primary evaluation sense [51] and reduces potential bias attributable to preconceptions about certain materials. Interaction with the exterior of mobile phones and other portable electronic devices is indeed largely tactile – the user's vision is focused on the screen, but their fingers are in constant contact with the largely unseen rear of the device. Zuo et al. [59] posit three types of touch: passive, active and intra-active. This study took an active mode of tactile evaluation “in which the stimulus is stationary and the subject actively explores [the] object or surface” ([59], p. 30). The participants were asked to take their time to feel each of the sample materials in any order.

To provide a basis for scale selection, scales chosen by Chuang et al. [14] for their work on user preferences towards mobile phones were used as a foundation with the exclusion of word pairs deemed unsuitable for materials evaluation e.g. obedient – rebellious. The selection of word pairs was also influenced by Baxter et al. [3]'s ‘sensorial properties’ and ‘indicators of use’. The bipolar word pairs used at this stage were: Cold – Warm, Sticky – Non sticky, Moist – Dry, Slippery – Firm hold, Soft – Hard, Smooth – Rough, and Dislike – Like. The participants

were asked to place the sample materials in order, e.g. from smooth to rough, depending on which word best described that material (Fig. 3). Once placed in order the participants were asked to give the sample materials a number from 0–10 depending on their position on the scale. Eleven scale points were used as this scale was used by Zuo et al. [58] with great success and it was felt that due to the large number of sample materials being used, eleven scale points would allow them to sufficiently distinguish between samples. An odd number of scale points were used to provide a midpoint for neutrality.

In Stage 2 the blindfold was removed from the participant following randomisation of the positions of the sample materials. The participants were then asked to look at the sample materials before being asked to place them on a scale of 0–10 depending on the bipolar words presented to them. The bipolar word pairs used at this stage were: Ugly – Elegant, Lively – Dull, Unsafe – Safe, Non-shiny – Shiny and Dislike – Like. For the sample materials placed at each end of the dislike – like scale, participants were asked to describe the reason for their feelings towards that material. The likeability scale is used in a wide range of material appraisal studies [13, 26, 33] and was, therefore, deemed to be suitable.

Stages 1 and 2 were then repeated using the artificially aged sample materials. In both stages, qualitative data relating to preference (e.g. Dislike–Like) was collected via digital dictaphone recordings which were subsequently transcribed. To ensure continuity in lighting, the same room was used throughout the study. However, it was not possible to account for changes in natural light due to differing times of day for the interview sessions. The room temperature and humidity could not be closely controlled.

Two pilot sessions were held to determine the suitability of the method and to resolve any methodological issues. During the testing the pilot participants stated that they had trouble with the word pair Moist and Dry. They explained that it was difficult to put the materials on this scale as none of them were really moist and it was almost the same as Sticky – Non sticky. Using this information it was decided to remove the Moist – Dry word pair from the testing as it was felt that this would not provide reliable results. The piloting also highlighted that repeating the word pairs Cold – Warm, Sticky – Non sticky, and Slippery – Firm hold with the aged sample materials was not necessary. The ageing process had no effect on these attributes, therefore using these word pairs again would not add to the data set. It was also determined that the relative positioning of word pairs with values that could be

influenced by heat or sweat generated by participants hands (i.e. Cold – Warm, Sticky – Non sticky, Moist – Dry and Slippery – Firm hold) was a crucial concern as these conditions may have a bearing on participant's responses. Therefore, the order was amended to place these pairs first.

4. Analysis methods

Interpretation of the data is conducted in two ways, through significance testing as well as descriptive analysis. Spearman's ρ (Spearman's rank correlation coefficient) is a non-parametric rank statistic that can be used to measure the strength of an association between two variables, without any requirement for a linear relationship between the two variables. The sample size required is 10 according to Chen & Popovich [12] making this statistical test appropriate for the data collected due to the small sample size of 15.

Thematic analysis identifies, analyses and reports patterns within data [5] and as such was seen as suitable for qualitative data analysis. The transcripts were analysed using thematic analysis with the aid of NVivo 9 (QSR International) and each interview was coded using the materials as categories. Once the first coding pass was complete, more in-depth coding was conducted with the creation of the nodes 'Blindfolded' and 'Seeing' within the material categories. These nodes were then split further into smaller nodes named 'New' and 'Aged', creating a coding tree with three levels.

5. Results

Results are presented for blindfolded (tactile) responses (Fig. 4) and seen (visual + tactile) assessment (Fig. 5), with the materials' 'likeability' presented in rank order for each test condition in Table 1. Overall these results show that the ageing process had a very limited affect on the tactile assessment of the materials, so despite severe wear the 'feel' of the materials was not significantly altered. However, the visual changes caused by the artificial ageing did result in significant changes in participant's assessment of the materials. Walnut in particular was seen to 'age badly' and became the least liked material after ageing. Similarly the like/dislike score for leather dropped significantly after ageing. The Like/Dislike scores of some materials, however, did increase after ageing: bamboo and cork increased slightly, but only by a small amount compared to the large standard deviation of the results. The rating of titanium increased significantly after ageing, and the standard deviation narrowed with almost all participants ranking this their most liked material after ageing.

The correlation between each word pair and 'Dislike – Like' was assessed using Spearman's rank correlation coefficients, with values of 0.2–0.39 described as 'weak' correlation, 0.40–0.59 as 'moderate', 0.6–0.79 as 'strong' and 0.8–1 as 'very strong' correlation (Tables 2 and 3). For example, a very strong positive (+) correlation between 'Ugly – Elegant' and 'Dislike – Like' means that participants liked materials which

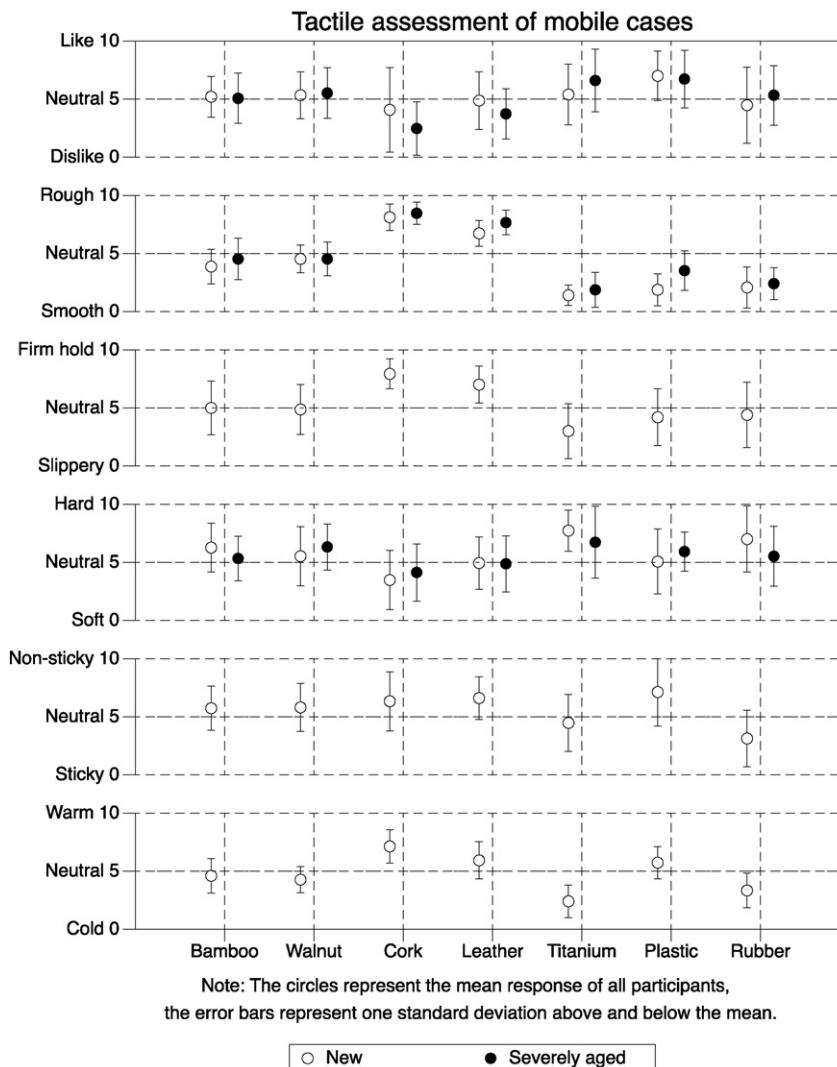


Fig. 4. Results from blindfolded (tactile) assessment of new and severely aged cases.

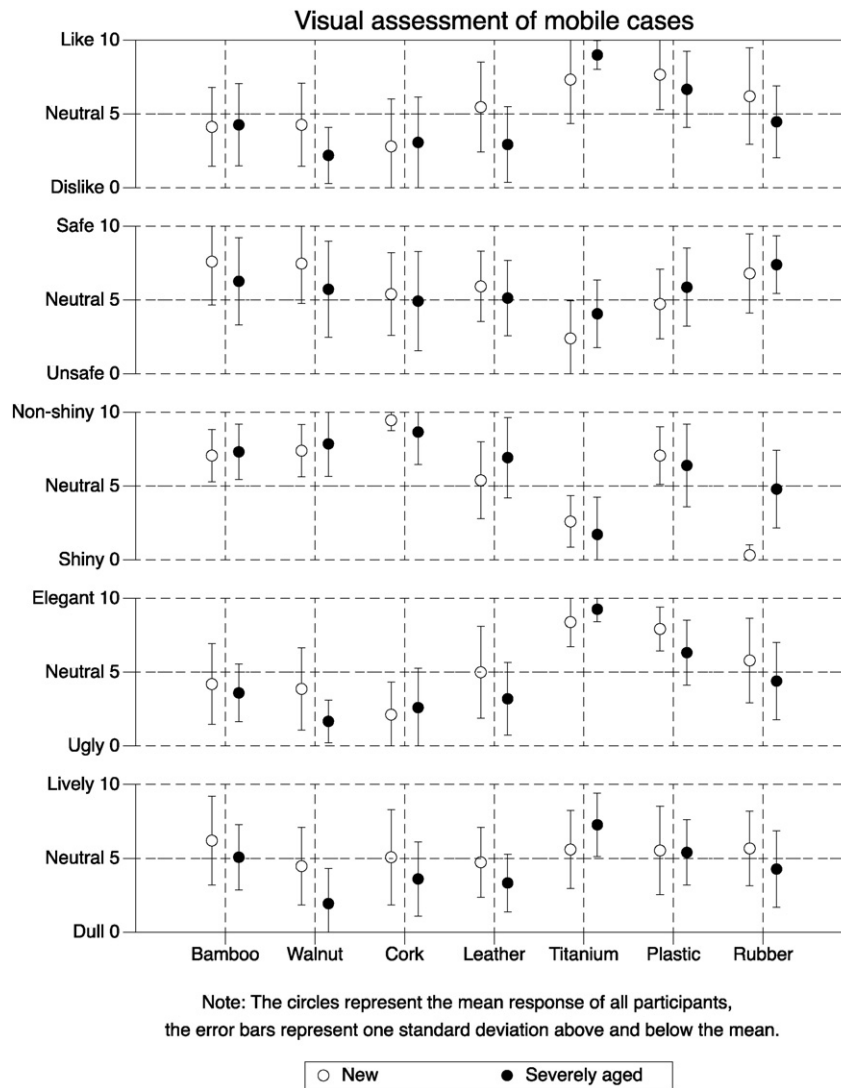


Fig. 5. Results from seen (visual + tactile) assessment of new and severely aged cases.

they classed as elegant, and disliked ugly materials. A negative (–) correlation would suggest the inverse relationship. For the new samples there is a very strong correlation between ‘like’ and ‘elegant’, and a strong correlation between ‘like’ and ‘slippery’, ‘smooth’ and ‘shiny’. These attributes are consistent with properties of materials typically used for electronic devices: smooth, shiny plastic or metal. After ageing there is a very strong correlation between ‘like’ and ‘hard’, ‘lively’ and ‘elegant’, with a strong correlation between ‘like’ and ‘shiny’. The

correlation between ‘like’ and ‘hard’ and between ‘like’ and ‘lively’ changed from ‘weak’ or ‘very weak’ for the new samples to ‘very strong’ for the aged samples. This may be because materials perceived as hard were less affected by the ageing process, and therefore increased in appeal compared to others which were seen as damaged or degraded by the ageing process. Similarly, participants appear to have labelled materials with obvious signs of ageing as ‘dull’, with materials which maintained a shinier finish after ageing described as ‘lively’.

Table 1
Rank order for ‘Dislike-Like’ for each test condition.

	Blindfolded (tactile) assessment				Seen (tactile + visual) assessment			
	New		Severely aged		New		Severely aged	
	Material	Mean score (SD)	Material	Mean score (SD)	Material	Mean score (SD)	Material	Mean score (SD)
Like (max 10)	Plastic	7.0 (2.1)	Plastic	6.7 (2.5)	Plastic	7.7 (2.4)	Titanium	9.0 (1.0)
	Titanium	5.4 (2.6)	Titanium	6.6 (2.7)	Titanium	7.3 (3.0)	Plastic	6.7 (2.6)
	Walnut	5.3 (2.0)	Walnut	5.5 (2.2)	Rubber	6.2 (3.3)	Rubber	4.5 (2.4)
	Bamboo	5.2 (1.8)	Rubber	5.3 (2.6)	Leather	5.5 (3.1)	Bamboo	4.3 (2.8)
	Leather	4.9 (2.5)	Bamboo	5.1 (2.2)	Walnut	4.3 (2.8)	Cork	3.1 (3.1)
Dislike (min 0)	Rubber	4.5 (3.3)	Leather	3.7 (2.2)	Bamboo	4.1 (2.7)	Leather	2.9 (2.6)
	Cork	4.1 (3.6)	Cork	2.5 (2.3)	Cork	2.8 (3.2)	Walnut	2.2 (1.9)

Table 2

Strength and direction of the correlation between word pairs and 'dislike - like' for new samples.

Tactile properties		Visual properties	
Word pair	Strength and direction of correlation to 'Dislike - Like'	Word pair	Strength and direction of correlation to 'Dislike - Like'
Cold - Warm	Weak (–)	Dull - Lively	Very weak (+)
Sticky - Non sticky	Weak (+)	Unsafe - Safe	Moderate (–)
Soft - Hard	Weak (+)	Shiny - Non-shiny	Strong (–)
Slippery - Firm hold	Strong (–)	Ugly - Elegant	Very strong (+)
Smooth - Rough	Strong (–)		

Results for the thematic analysis of qualitative data are presented for each material in turn, with a particular focus on the effects of ageing on user perceptions:

5.1. Walnut

Perceptions of the walnut sample were adversely affected by the ageing process, falling from 5th to 7th in the overall order of preference ranking. The qualitative comments made whilst blindfolded revealed that although changes in the material surface were noticeable, they did not reduce perceptions of tactile quality:

"This one feels alright, I can feel the wear and tear but it still feels ok"

"It [bamboo] doesn't feel like there is any damage on this one, it holds up basically, and same with this one [walnut] actually, I don't feel, like, any scratches or maybe in the corners a bit but, it just feels really steady, sturdy sorry".

Participants' appraisal of the tactile quality was, however, affected by seeing the aged sample, with one participant, who previously felt the walnut case "felt ok" stating that;

"The wood [has] got rougher with time, it was a lot smoother in the beginning and now it's quite rough around the edges...I'd be scared of splinters".

This implies that although users may be more forgiving of abrasion, impact or ablation resulting in deeper splits or cracks in the material may prove less acceptable. When the aged walnut sample was visually inspected participants' views became overwhelmingly negative:

"I wouldn't expect it to be that worn away"

"You can really see the fade marks"

"Clearly looks like it's well worn"

"This one is worn... it looks worn"

"This one [walnut] has got more scratched and damaged"

In one case, the participant mentioned that this dissatisfaction would prompt early disposal:

"It just looks bad. It wears away too quickly, and it looks like not anything near what it started off like. At that point most people would consider replacing it."

5.2. Bamboo

In contrast to walnut, bamboo showed no significant change in 'Dislike-Like' score after ageing, but did change from being ranked 6th in order of preference when new to 4th when aged. This is reflected in the qualitative responses when blindfolded;

"It [bamboo] feels like it's aged quite well. It's not really rough, it just shows a couple of dents, well not dents, but scratches where it's been used obviously but it's aged quite well"

and when seen:

"Obviously it's [a] very durable material even after its general wear and tear".

In some cases, the added wear enhanced the visual appeal.

"[the] bamboo still looks alright. I prefer that bit to it [worn] to the shiny bit actually. I like the worn bit, looks good, the shiny bit looks like laminate flooring".

The lesser impact of wear on the bamboo, in comparison to the walnut, was largely attributed to its lighter surface finish, and in many cases this rendered the wear "acceptable";

"It's [bamboo] lost a bit of colour and looks like someone has sanded it. Because it's a lighter version, it's bamboo, it's not as noticeable so I wouldn't mind so much"

"The only reason this [bamboo] isn't a zero as well, is because it's a lighter colour so you can see it [the damage] a bit less."

5.3. Cork

The cork sample was the most disliked pre-ageing, but despite largely negative comments post-ageing, it was ranked slightly higher

Table 3

Strength and direction of the correlation between word pairs and 'dislike - like' for aged samples.

Tactile properties		Visual properties	
Word pair	Strength and direction of correlation to 'Dislike - Like'	Word pair	Strength and direction of correlation to 'Dislike - Like'
Soft - Hard	Very strong (+)	Dull - Lively	Very strong (+)
Smooth - Rough	Strong (–)	Unsafe - Safe	Very weak (+)
		Shiny - Non shiny	Strong (–)
		Ugly - Elegant	Very strong (+)

in order of preference afterwards. When blindfolded, dislike arose in relation to the surface roughness which was described as 'worn' 'tired' or 'old':

"This one is quite rough on the side where it's been so beaten up, which isn't very pleasant, and... I don't like the uneven texture"

"This one [cork] feels a bit tattered, worn", "This [cork] one's rough, definitely rough, the majority of it"

"It [cork] feels like it's quite worn, the textures quite rough, it doesn't feel as nice to hold, yeah it just feels old"

Some participants found the lack of surface uniformity displeasing:

"It feels very worn, it's not just rough it's an uneven texture, in terms of some parts feel rougher than others", "...some rough areas, not uniform".

Yet, interestingly, when they saw the aged sample some participants felt it had aged less noticeably than other materials;

"That [cork] doesn't look that different. The rest look a bit older"

or than the new sample:

"It [cork] feels like if it's been up to two years of wear it still hasn't changed that much from what it was when it was originally"

In some cases, the material qualities such as the surface roughness and non-uniform patina were considered beneficial in reducing ageing effects:

"This one [cork] kind of has a rough texture so it hasn't change that much and even if it does you can't really tell because that's the style"

"I just feel like if there is any damage or anything it doesn't show and the type of material it is, cork, it you expect it to be rough".

The general dislike for this material applied within this context somewhat nullified this potential benefit. Some participants felt the case would protect the phone, they did, however, observe surface changes such as dents, chips, fading and damage which reduced the overall appeal:

"I think it's the colour of it [cork] it just looks a lot more tired and is wearing out on the edges as well... but yeah I just think it looks tired and more dull in colour than it was before"

"I can feel the damage on side of this one [cork] which feels really horrible"

"That one [cork] has stayed quite well though, compared to the rest... oh actually, no it's not [inspects edge damage]"

"It's really worn through and discoloured the cork one has a lot more indents and pieces of cork missing"

5.4. Titanium

Following visual assessment of the aged titanium, it became the most liked material, with a significant reduction in standard deviation indicating that this was the most liked material for almost all participants. However, this may have reflected a decrease in desirability of

the other materials, rather than a positive change in perception of the titanium. Comments about the titanium were largely unaltered following ageing as little discernable material change was noticed, either whilst blindfolded or when seen:

"It doesn't feel as if it's worn that much at all"

"I don't recognise that that has changed at all"

Moreover, participants felt it had aged well

"This one [metal] seems like it's close to brand new, there are hardly any imperfections on it. I couldn't feel any difference"

was durable;

"It's [metal] kind of had less fade on it and in comparison it's shinier, shinier than before. It's not faded that much, it's more durable"

and had minimal wear (at a level considered acceptable given the use period simulated);

"It [metal] hardly looks aged. It's the less damaged of them all. Minuscule scratches, hardly noticeable"

"There's a few scratches you'd expect"

and therefore would encourage longer term ownership;

"It looks good, and it's something you can have for a long time without having to replace it"

"It [metal] still looks near enough the same condition, it's durable, you get your money's worth with this one".

5.5. Plastic

For both tactile and visual assessment, the new plastic was the most 'liked' material. Following ageing, the like rating reduced and it dropped to second place behind titanium. However, participants' views of the plastic case were largely unchanged by the artificial ageing. Though some evidence of wear was observed in the form of slight discolouration, increased surface roughness or accumulation of dirt, this was considered minor or superficial and as such did not detract from users' preference:

"I still like it [plastic] even though it's a tiny bit rough, but it's not that big of a deal to be honest I still like the feel of it"

"This one [plastic] has also changed but I don't really mind as much"

"This [plastic] shows signs of wear and tear but you might get away with it".

5.6. Leather

For visual assessment of the new leather, it was the most 'liked' of the natural materials, and the only natural material to score greater than 5 on the dislike-like scale. However, following ageing the dislike-like score dropped from 5.5 to 2.9. Before ageing, the colour and texture of the leather sample elicited mixed responses with some participants liking the colour but not the texture and vice versa:

"I really don't like the feel of leather"

"I quite like the texture of that one [leather], but the colour I don't like"

"I quite like the brown colour"

or neither;

"I don't really like the texture [leather], and I don't really like the colour"

Perceptions of the leather sample were adversely affected by the ageing process, falling from 4th to 6th in the overall order of preference ranking. The qualitative responses indicate that this was due to the observed discolouration, ablation (chipping, dents), accumulation of dirt and increased "roughness" of the surface finish:

"The leather is discoloured so it makes it look quite dirty"

"It [leather] looks really dirty especially the brown colour at the top, it looks a bit grim, especially on the side here, it's not very clean"

"It's the colour [leather], not just any colour but looks faded into a dirty colour"

"Now that it's [leather] been used the colour is discoloured"

Two participants, however, cited benefits from the ageing process and a corresponding increase in appeal:

"Now that it's a bit worn it looks a bit more authentic, and it appeals more... it just looks much more like it's been, it looks well loved"

"This one [leather] seems to have gotten better with age... I think it [ageing] kind of adds to it [leather] in some ways. It's probably been aged a bit too much, but, kind of reminds you of an old book".

5.7. Rubber

Participants all agreed that the rubber was very shiny (scoring 0.33 on the shiny/non-shiny scale), and this changed significantly with ageing (4.8). The corresponding Dislike-Like scores dropped from 6.2 to 4.5. Prior to ageing, the rubber sample divided participants' opinions, those who rated it highly in terms of its visual and tactile appeal cited its protective qualities, sleekness and 'shininess'; those for whom it lacked appeal described it as "sticky", "slimy" and "cold". The clearest visual change noted by most respondents post-ageing, was that the 'shininess' of the material had diminished;

"Because it's lost its shine which for me was the appealing factor, it looked really shiny and pristine whereas [that] one looks quite battered and the texture has changed, it's a bit more sticky"

"It's [ageing] really ruined it...it just doesn't have the same look to it anymore"

"It's still quite shiny but, yeah, it's quite tarnished now"

Though some participants noted that the colour had faded and the surface had accumulated dirt, smudges and minor scratches the material was, however, considered hardy and resistant to the more noticeable wear displayed on other test materials:

"I think it's [rubber] aged quite well. I mean the back is a bit scruffy but other than that it's aged, compared to the others, it's got less scratches and wear and tear".

6. Discussion

User's perceptions of materials change over time influenced by previous use and experience [18,27]. This study did not, however, capture the element of time – including the rate of ageing and surface change, whether particular changes were related to events in the user's life, and whether the user had cared for, protected and repaired the item through its life. This is due to the short duration of the study and the use of products which were not owned by participants. There are three different levels to the function and processing within the brain: visceral, behavioural and reflective [40]. These three levels prompt distinct responses to products [34]. The visceral level deals with automatic, rapid judgements of what is good or bad, it is perception based and is concerned with product appearance (ibid). Due to the relatively short appraisal permitted in this study, participants' responses to the materials can be considered visceral rather than reflective. Additionally, as the ageing process did not occur naturally with the passage of time, participants could not acclimatize to gradual material changes or be shocked and disappointed by sudden damage.

A further limitation pertained to the dimensions of each material sample. Whilst all of the cases were applied to the same size and weight dummy phones, the thickness of the cases varied. Unfortunately this meant that the bamboo and walnut samples were slightly larger than the other materials, reinforcing people's preconceptions that these are 'chunky', 'low-tech' materials. It would be worthwhile to present these materials in the same form as the 'sleeker' metals (e.g. metal and plastic) to challenge people's perceptions and invite their response to the material and its context, without the influence of form.

The strongest theme that runs through the results is the contrasting views of the different participants about almost every aspect of the materials studied, making it difficult to draw broadly applicable conclusions. The lack of clear trends in the findings may be due to the small number of participants ($n = 15$); a larger sample may reveal more. Unfortunately, the data collection methods used in this study are time consuming making a large study (i.e. $n = 50 +$) difficult.

Participants' opinions of the materials are shaped by a combination of factors: tactile response, aesthetic judgement, preconceived feelings about each material (regardless of context), preconceptions about which materials they expect to see in the context of a mobile phone, and comparison of the different materials used in the study. In the context of the mobile phone the participants referred to a wide range of often conflicting 'requirements' for the material: sleek but strong, simple but distinctive, smooth but grippy.

Whilst in general participants preferred the new materials and saw the ageing process as negative, there are some examples where the aged samples either scored more highly (titanium) or received positive comments (bamboo and leather). The 'Dislike-Like' score for titanium increased after ageing making it first choice for most participants. This was based on durability; participants were impressed that the material had survived the harsh treatment so well, which had caused more significant changes to the other materials. This was a relative judgement, if the changes to the titanium were seen in isolation the participants may have been more critical. Whilst not reflected in the average scores, there were isolated comments which suggested that the artificial ageing had improved the aesthetics of the natural materials: for the bamboo *"I like the worn bit, looks good, the shiny bit looks like laminate flooring"*, and for the leather *"now that it's a bit worn it looks a bit more authentic, and it appeals more... it just looks much more like it's been, it looks well loved"*. If natural materials are too smooth, shiny and 'well' finished we might question whether they are in fact natural, in this case some ageing

shows the character of the natural material and provides a more appealing surface finish [45].

If we rely on average 'Dislike-Like' scores we find that the conventional materials for mobile phone enclosures (plastic and titanium) are the most desirable. The popularity of plastic in this study contradicts previous work: "*Plastics cease to function, become evidently worn, in a particular way. They 'traumatise' they do not patinate; they gather dirt rather than 'charm' and when they do they elicit feelings of disgust particularly strongly*" [20]. However, people's perceptions of materials are closely linked to their context, with materials which are commonly used being more likely to be accepted through familiarity: "*...in particular circumstances plastic affords disgust, in others delight*" [20]. 'Plastic' refers to a broad range of materials, and describes materials which have been extensively developed and improved through time. Whilst early plastics were very brittle, and some plastics still remain susceptible to discolouration and embrittlement following exposure to ultraviolet light, plastics can be made to be hard and durable, and therefore exhibit little obvious wear in consumer products [2]. The plastic used in this study was ABS (Acrylonitrile Butadiene Styrene), a common thermoplastic polymer with good impact resistance and toughness used in high quality, durable toys such as Lego.

Natural materials are often considered to be appealing and environmentally friendly, and as such can play an important role in the commercial success of a product [42]. However, in the context of a portable electronic device natural materials such as walnut and cork are unexpected, and they divided opinions in the response to both their tactile and aesthetic properties. The difference in response from blindfolded to visual inspection may be due to the visual response (the dominant sense) overriding tactile considerations, and it may also be due to preconceptions about a particular material once visual inspection revealed the material type. This was particularly true for leather, with a strong move towards 'dislike' once participants knew that the material was leather.

It can be observed from participant responses that material finishes and colours affected participants' perceptions of wear. The colour of the walnut and bamboo samples and their response to artificial ageing impacted on perceptions of their longevity. The darker the sample, the more noticeable and detrimental the wear. Three different participants commented: "*Because the wood [bamboo] is a light colour the fading doesn't look as bad as that one [walnut] that is a darker colour, so you could probably get away with having this for much longer*", "*I actually think that the light colour ages better than the dark colour... the darker colours have aged more evidently*" and "*With the wood, the dark wood it's quite visible, the wearing of, I don't know if it's the varnish or something on it*". The exact choice of material, surface finish and any treatment profoundly affected the ageing process. In this study the bamboo surface was lacquered and the main ageing mechanism was scratching and chipping of the lacquer rather than the bamboo itself.

Some material qualities positively impacted user perceptions after ageing. The entropy displayed within the surface of the cork, for example, ensured that post-ageing signs of wear and tear were less noticeable. The notion of entropy as a means to extend product lifespan by reducing noticeable wear has previously been incorporated in products such as Entropy © carpet tiles by interface and represents an intriguing design strategy for prolonging life-spans in other product types.

Comparison with the gentle ageing study [63] provides a more nuanced understanding of participants' responses to the ageing process. In general the gentle ageing was too subtle to change the participants' rankings significantly, with opinion divided about whether the ageing process increased or decreased the desirability of the materials. Walnut is an interesting example: with gentle ageing the dislike-like score for visual assessment went up by 0.7 from 5.0 to 5.7 (Authors, 2015), for severe ageing this score dropped by 2.1 from 4.3 to 2.2. It was anticipated that the leather and walnut samples would 'age well' and that their relative 'likeability' would have increased with ageing, but this was not the case. The accelerated ageing test developed for this work provides a

reasonable simulation of wear and damage in use, but does not currently include other material specific effects which may be required to achieve graceful ageing of particular materials. For example, leather is easily damaged by abrasion, but responds well to repeated polishing, flexure and oiling. For wood, long term exposure to ultraviolet and visible light are required to enhance the figure (grain patterns). Material specific ageing mechanisms can also result in degradation, such as UV discolouration in plastics which is perceived to result in dissatisfaction [20].

7. Conclusions

The most striking observation across all aspects of the study were the diverse and contrasting views of the participants, with differences between participants, and conflicting desires of a single participant (e.g. sleek and shiny yet easy to grip). This suggests that finding an optimal material, even for a small sub-set of potential users, may be difficult.

The ageing process affected the position of some of the sample materials in preference order. Bamboo, cork and titanium gained favour, whereas average perceptions of leather and walnut were adversely affected. The samples showing the least wear were rated more highly and considered more desirable, implying that most participants preferred durable materials that showed as few signs of ageing as possible. The notion that participants may prefer natural materials that age 'gracefully' was unsubstantiated by the quantitative data in relation to leather and walnut as the majority of participants disliked how these samples looked following the ageing process. Whilst not reflected in the average scores, there were individual comments which suggested that the artificial ageing had improved the aesthetics and desirability of these materials.

The study reported on in this paper set out to explore attitudes to materials which have become 'tired', 'worn' or 'damaged' to better understand factors influencing early disposal due to cosmetic obsolescence. To achieve 'graceful ageing' as opposed to 'wear' and 'damage' designers need to carefully consider the interplay of material choice, form, surface finish, ageing processes and maintenance [45]. Resources for designers in this area are very limited: there are no standard test procedures for simulating material ageing in use, and materials libraries [1] present pristine material samples, which only represent the briefest phase of a product's life. Wilkes et al. [55]) describe the scope for designers to influence material development to achieve specified sensoraesthetic, as well as functional, material properties, but again the materials considered are in new condition, with no consideration of wear, ageing or deterioration in use. A library of materials which compares the pristine surface to various forms of deterioration, damage and graceful ageing, accompanied by details of the associated ageing processes, would provide designers with new insights into the possible futures of the objects they design.

To move from simulation of typical wear on devices made from metals and plastics, to achieving graceful ageing of natural or synthetic materials careful consideration of these parameters including use of crafted material samples and refinement of the accelerated ageing process to include a wider range of ageing processes and maintenance is needed.

This study captured the participants' immediate, visceral response to the materials, which may be very different to their feelings towards materials and objects that they have owned and interacted with for a period of time. This is particularly true of damage, which may be interpreted very differently depending when it happens: a scratch caused by dropping a new phone is different to a gradual buildup of wear, or a scratch caused by an interesting event in the owner's life [29,35]. Further exploration of the influence of time, ownership and interaction on user perceptions of material ageing is, therefore, required.

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